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Rain water harvesting, silvipastoral and goat based integrated farming system model for livelihood resilience in drought-prone rainfed semi-arid tropics

Palsaniya, DR*[1]; Kumar, S[2]; Das, MM[1]; Rai, SK[1]; Kumar, S[1]; Kumar, TK[3]; Chaudhary, M[4]; Chand, K[5]; Ahamed, A[6]; Sahay, CS[7]

[1]ICAR-Indian Grassland and Fodder Research Institute, Jhansi, Uttar Pradesh, India

[2]ICAR- Indian Institute of Farming System Research, Modipuram, Uttar Pradesh, India

[3]ICAR-Central Tobacco Research Institute, Rajahmundry, Andhra Pradesh, India

[4]ICAR-Indian Agricultural Research Institute, Hazaribagh, Jharkhand, India

[5]ICAR - National Institute of Agricultural Economics and Policy Research, New Delhi, India

[6]ICAR- Research Complex for Eastern Region, Patna, Bihar, India

[7]ICAR- Central Institute of Agricultural Engineering, Bhopal, India

*Corresponding author Email: drpalsaniya@gmail.com, ORCiD: 0000-0002-1668-1352

Keywords: Rainfed farming system; Rain water harvesting; agroforestry; intensification; Livelihood; Resilience

Abstract

Rainfed areas are the home of millions of resource poor farmers whose livelihood is under continuous threat due to frequent droughts. Assured cropping and imparting livelihood resilience to livestock keepers is a challenge. A study was planned during 2013 – 2019 for livelihood resilience of rainfed farmers through rain water harvesting and silvipasture based interventions. The one hectare rainfed farming system model comprising of rain water harvesting farm pond (25 m x 20 m x 2.5 m), less water requiring food crops (groundnut–barley and sorghum–chickpea), agrihorticulture [*Ziziphus mauritiana*+(*Sesamum indicum–Cicer arietinum*)], silvipasture (*Leucaena leucocephala*+Tri-species hybrid grass+*Stylosanthes hamata*) and boundary plantation (*Leucaena leucocephala* and *Opuntia ficus-indica*) was evaluated at research farm. The goat rearing potential of the above model was also estimated under intensive and semi-intensive systems. The rainfed farming system module produced 4979 kg ha^{-1} barley equivalent yield consisting of multiple products like barley, chickpea, groundnut, Indian jujube fruits, sesame, fodder (sorghum, TSH, *Stylosanthes, Leucaena* dried leaf meal and spine-less fodder cactus cladodes) and *Grewia* fruits and resulted in 655 US$ year^{-1} net returns with a benefit cost ratio of 2.1. The carrying capacity of the model was 9 and 35 goat year^{-1} under intensive and semi-intensive rearing systems, respectively. The net returns increased by 36 and 226% with the inclusion of goat under intensive (US$ 892) and semi-intensive rearing system (US$ 2136), respectively in the model. It was evident from the study that inclusion of goat, silvipasture and farm pond for rain water harvesting in the rainfed farming have resulted in higher profitability and resilience to less rainfall and its aberrations. It can be concluded from the study that water harvesting, silvipasture and goat

in rainfed farming systems could enhance the productivity and profitability and impart resilience to the livelihood of rainfed farmers in semi-arid tropics.

Introduction

Rainfed agriculture has special significance in terms of ecology, farm productivity and livelihood for millions of resource poor farmers and livestock keepers especially in arid and semi-arid tropics. Rain water harvesting cum efficient recycling and agroforestry based intensification offer a great opportunity for enhancing productivity, natural resource conservation, risk proofing and sustaining livelihood of farmers practicing rainfed agriculture (Palsaniya et al. 2021). Inclusion of animal components, especially small ruminants like goat, in such farming systems may further improve the profitability and resilience of the production system. However, the systematic information on water harvesting – crop – agroforestry – animal integration under rainfed situation is scanty and therefore, need to be researched upon. There is also a need of exploring and calculating the carrying capacity potential and possible economic benefits of such rainfed models under stall feeding and semi-intensive animal rearing systems. Therefore, the present investigation was carried out to establish the impact of rain water harvesting, agroforestry and goat based intensification on livelihood resilience of rainfed smallholder farming systems of India.

Materials and methods

The field experiment was carried out at the Central Research Farm of ICAR-Indian Grassland and Fodder Research Institute, Jhansi (Uttar Pradesh), India during 2014–2018. The soil of the site was sandy loam in texture, low in available N and K and medium in available P and soil organic carbon (0.58%). The components of one hectare rainfed farming system model are shown in table 1. Boundary plantation of *Leucaena leucocephala* and *Opuntia ficus-indica* was also there. The goat rearing potential of the above model was also estimated under intensive and semi-intensive rearing systems. The animals were stall-fed under the intensive system while they were allowed to graze in community and fallow lands and partially supplemented with farm forages, under the semi-intensive system. The life cycle assessment and process analysis approach was used in the present study (Jianbo 2006; Palsaniya et al. 2023). A detailed inventory of inputs and outputs of all the components of the rainfed farming module was compiled. The production cost and returns from individual components were calculated using prevailing market prices of their respective inputs and outputs. The gross return from each component was calculated by multiplying the quantity of produce by its prevailing market price. The total cost was deducted from the gross return to calculate the net return while the benefit cost ratio (BCR) was calculated by dividing gross returns by total cost.

Table 1 Components of the rainfed farming system model

Enterprise	Area (ha)	Component (ha)	
		Rainy season	Winter season
Food crops	0.55	Groundnut (0.3)	Barley (0.3)
		Sorghum (0.25)	Chickpea (0.25)
Silvipasture	0.2	*Leucaena* + Tri-species hybrid grass + *Stylosanthes*	
Agrihorticulture	0.2	Indian jujube + (Sesame – Chickpea)	
Boundary plantation	-	*Leucaena* and spineless fodder cactus	
Rain water harvesting pond	0.05 (20 m × 25 m × 2.5 m)	*Grewia asiatica* on pond dykes	
Total	1.0		

Results and discussion

The component yield, productivity and economics in rain water harvesting and agroforestry based improved rainfed farming system model are presented in Table 2. The food crops in the model consisted of groundnut, barley and chickpea, which on an average, produced 240, 1021 and 311 kg grain yield, respectively. Among the food crop components, the highest barley equivalent yield (BEY) was observed in barley (1021 kg) followed by chickpea (925 kg) and groundnut (718 kg). On an average of 4 years, 200 kg Indian jujube fruits, 81 kg sesame and 179 kg chickpea grain yield was produced from the agrihorticulture component in the model. The equivalent yield in terms of barley was the highest for chickpea (532 kg) followed by sesame (283 kg) and Indian jujube (144 kg) in the agrihorticulture block. Fodder sorghum produced 2314 kg green fodder which was equivalent to 581 kg BEY. The silvipastoral module recorded 2051 kg green fodder (BEY, 129 kg) from TSH, 2233 kg green fodder (BEY, 180 kg) from *Stylosanthes* and 203 kg *Leucaena* dried leaf meal (BEY, 204 kg). The boundary plantation produced 1600 kg fresh spine-less fodder cactus cladodes (BEY, 115 kg), 110 kg *Leucaena* leaf meal (BEY, 111 kg) and 5 kg *Grewia* fruits. Apart from this, the various food crops in the model produced a total of 2741 kg dry fodder year^{-1} comprising of barley straw (1496 kg), groundnut stover (325 kg), sesame stover (207 kg) and chickpea stover (405 kg from food crop component and 308 kg from agrihorticulture). In total, the rainfed farming system module produced 4979 kg ha^{-1} barley equivalent yield consisting of the multiple products above reported. The total cost of cultivation, gross returns, net returns and benefit cost ratio of the one ha rainfed farming system model were 589 US$, 1244 US$, 655 US$ and 2.1, respectively. The contribution of food crop components (446 US$) was the highest (62.9%) in the total net returns of the model, followed by agrihorticulture (137 US$, 19.3%), silvipasture (75 US$, 10.6%) and boundary plantation (51 US $, 7.2%).

The carrying capacity of the rainfed farming system model was found to be 9 and 35 goats year^{-1} under intensive and semi-intensive rearing systems, respectively (Table 3). Nearly 294 and 459 US$ initial investment was needed for animal shed, fencing, equipment and electric and water tank installations under intensive and semi-intensive rearing systems, respectively. The yearly fixed cost due to the initial investment was found to be 41 and 65 US$ under intensive and semi-intensive rearing systems, respectively. The variable cost under intensive and semi-intensive small ruminant rearing system was 1293 and 3026 US$ year^{-1}, respectively and consisted of animal cost, feed and fodder cost, labour cost, veterinary expenses and other miscellaneous cost. The feed and fodder cost was found to be the major cost (46%) followed by animal cost (30%), labour cost (21%) and others in intensive rearing system while animal cost, labour and feed and fodder constituted 50, 28 and 19% of the total variable cost in semi-intensive rearing system.

The gross return from the intensive rearing system was US$ 2226 and consisted of returns from meat (US$ 1740, 78%), skin (US$ 35, 2%), manure (US$ 75, 3%) and sale of non-edible produce (US$ 377, 17%). On the other hand, the semi-intensive rearing system yielded US$ 5226 gross returns out of which, 87% (US$ 4560) was from animal meat, 3% (US$ 135) from skin, 3% (US$ 179) from manure and 7% (US$ 352) from sale of non-edible produce from the model. The intensive and semi intensive small ruminant rearing system produced US$ 892 and 2136 net returns, respectively with almost similar benefit cost ratio. It is evident from the study that inclusions of small ruminants in rainfed farming model both as intensive and semi-intensive systems can enhance the profitability of the family farm. The net return from the rainfed farming system was US$ 655 which can increase to US$ 892 and 2136 if small ruminants are included under intensive and semi-intensive systems, respectively. The net returns increased by 36 and 226% on inclusion of goat under intensive and semi-intensive rearing system, respectively in the water harvesting and agroforestry based rainfed farming system model.

The inclusion of goat, agroforestry (tree) and farm pond for rain water harvesting in the rainfed farming resulted in higher profitability and resilience to reduced rainfall and its aberrations. In the rainfed farming system model, no crop failure was observed due to the presence of the farm pond, where rain water was harvested and efficiently utilized, when needed, through a sprinkler system for irrigation of crops. Further, the resilience in net income was the highest (2136 US$ ha^{-1}) when goat rearing was included under semi-intensive system followed by intensive system.

The increased and assured production and profitability of the IFS model might be due to the positive interactions and synergies among its components. The proper resources and by-product recycling among various components under the IFS resulted in higher productivity and income. The components in IFS interact synergistically and the by-product or output of one component is used as input in another, which minimizes the external dependence and leads to higher productivity, income and resilience (Palsaniya et al. 2017). Panwar et al. (2018) reported that the perennial components and livestock provide risk proofing to the farmer as they are more stable and less prone to aberrant weather conditions than annual food crops. Other researchers also observed that greater synergies, positive interactions and proper resource recycling among the components of IFS were mainly responsible for enhanced productivity, income and resilience (Kumar et al. 2018; Palsaniya et al. 2022).

It can be concluded from the present study that intervention of water harvesting, agroforestry and goats in the rainfed farming systems could enhance farm productivity and profitability and impart resilience to the livelihood of farmers.

Table 2 Yield, barley equivalent yield (BEY) and economics under rain water harvesting and agroforestry based rainfed farming system (mean of 4 years)

Particulars	Component*	Yield (kg plot^{-1})**	BEY (kg plot^{-1})	Cost of production (US$)***	Gross returns (US$)	Net returns (US$)	B:C ratio
Food crops	Groundnut	240 ± 41 (325 ± 55)	718 ± 72	103	165	62	1.6
	Barley	1021 ± 47 (1496 ± 105)	1021 ± 91	114	298	184	2.6
	Sorghum	2314 ± 170	581 ± 59	55	123	68	2.2
	Chickpea	311 ± 30 (405 ± 67)	925 ± 86	86	218	132	2.5
Agrihorticulture	Indian jujube	200 ± 50	144 ± 36	22	15	-7	0.7
	Sesame	81 ± 6 (207 ± 33)	283 ± 45	35	66	32	1.9
	Chickpea	179 ± 29 (308 ± 74)	532 ± 53	66	178	112	2.7
Silvipasture	TSH grass (GFY)	2051 ± 402	129 ± 27	13	32	19	2.5
	Leucaena (LM)	203 ± 51	204 ± 48	12	39	27	3.3
	Stylosanthes (GFY)	2233 ± 126	180 ± 31	10	39	29	3.9
Boundary plantation	Cactus +	1600 ± 300	115 ± 20	6	25	19	4.2
	Leucaena +	110 ± 17	111 ± 17	10	30	20	2.9
	Grewia	5 ± 1	38 ± 4	4	16	12	4.1
Farm pond	-	-	-	53	-	-	-
Total (1 ha)	-	-	4979	589	1244	655	2.1

*Where TSH, GFY and LM are tri-species hybrid, green fodder yield and leaf meal, respectively.
**Figures in the parenthesis are by-product of the crop and the value after ± is SE.
***The currency mean exchange value: 1 US $ = 65 Indian Rupee (₹)

Table 3 Goat carrying capacity and economic potential of the rainfed farming system model under intensive and semi-intensive rearing systems

Particulars	Goat rearing system	
	Intensive	Semi-intensive
Carrying capacity		
DM availability from model (kg ha^{-1})	3150	3150
DM required for 1 growing goat (15-38 kg body weight) (kg year^{-1})	350	90
Carrying capacity of model (goat ha^{-1})	9	35
Initial investment (US $)		
Animal shed	218	341
Fencing	49	58
Equipment	16	40
Electricity and water tank installation	10	21
Total initial investment	294	459
Interest on investment (@ 7%/annum) – A	21	32
Junk value	77	108
Length of useful life (years)	25	25
Yearly depreciation – B	9	14
Amortization cost – C	12	18
Yearly fixed cost due to initial investment (A+B+C) – D	41	65
Variable cost (US $)		
Animal cost	388	1508
Feed and fodder (from model)	589	589
Labour	267	842
Veterinary care	21	32
Miscellaneous expenses	29	55
Total variable cost – E	1293	3026
Total cost (D + E)	1334	3090
Returns (US $)		
Meat	1740	4560
Skin	35	135

Manure	75	179
Return from sale of non-edible produce from model	377	352
Gross returns	2226	5226
Net returns	892	2136
B:C ratio	1.66	1.69
Net return goat^{-1}	99	61

Decimal values are rounded to its nearer value; 1 US $ = 65 Indian Rupee

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